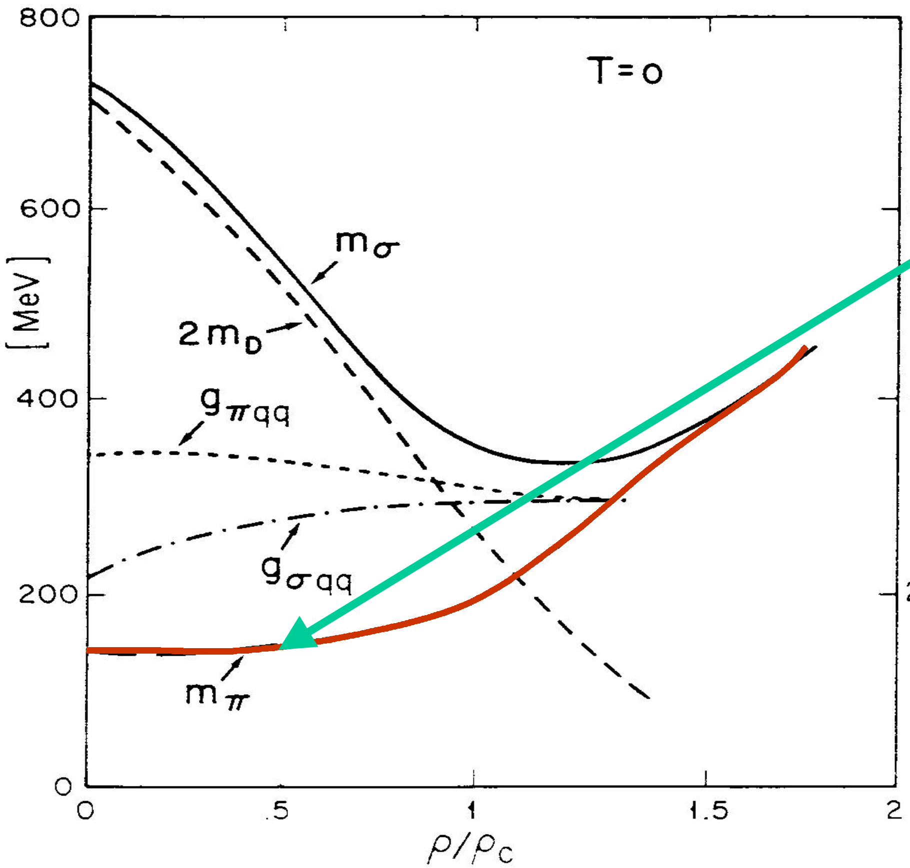
The Parton Momentum Distribution in the Nuclear DIS Region and the EOS

Jacek Rozynek INS Warsaw

Santa Fe 2005

EOS in NJL



Bernard,Meissner,Zahed PRC (1987)

EMC effect

- pion mass in the medium in chiral symmetry restoration
- Nucleon mass in the medium

Relativistic Mean Field Problems

In standard RMF electrons will be scattered on nucleons in average scalar and vector potential:

$[\alpha \mathbf{p} \; + \; \beta(M+U_S) - (e - U_V)]\psi = 0$

where $U_S = -g_S / m_S \rho_S$ $U_V = -g_V / m_V \rho$

$U_S = 300 MeV \rho / \rho_0$

$U_V = 300 MeV \rho / \rho_0$

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Gives the nuclear distribution f(y) of longitudinal nucleon momenta $p_+=yM_A$

$f(y) = f(y,\mu)$

μ – nucleon chemical pot.

Strong vector-scalar cancelation

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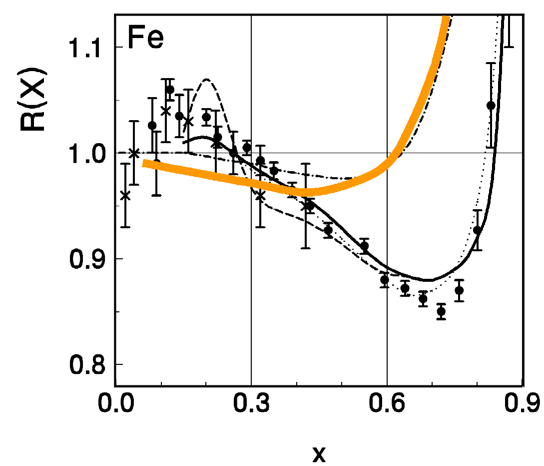
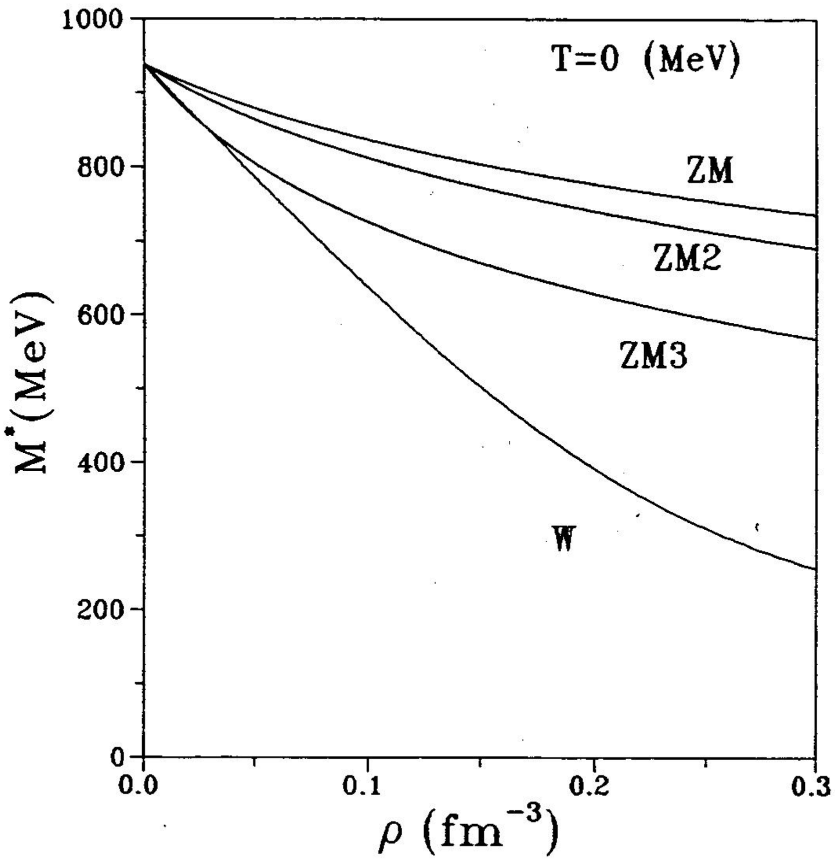


Effective Mass in RMF



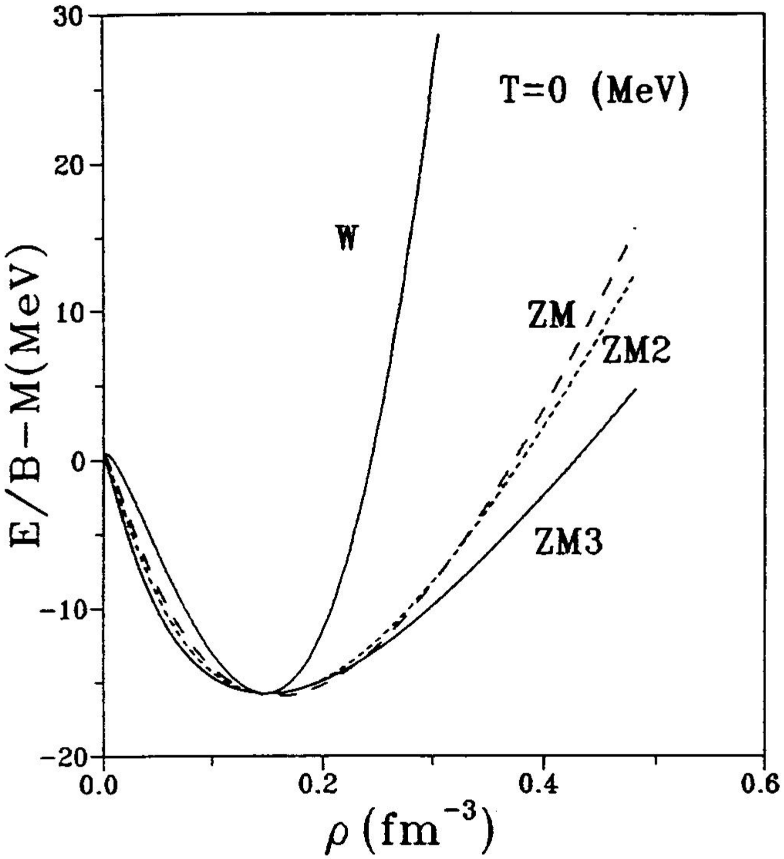
- W - Nucleon bare mass in the Walecka mean field approach

- ZM - constructed by changing of covariant derivative in W model. Langrangian describes the motion of baryons with effective mass and the density dependent scalar (vector) coupling constant.

ZM - Zimanyi Moszkowski

Relativistic Mean Field & EOS

quark condensate $<\bar{q}q>_m$ in the medium $\to 0$



$$\frac{<\bar{q}q>_\rho}{<\bar{q}q>} = 1 - \rho \frac{\sigma_{eff}}{m_\pi^2 f_\pi^2}$$

$$\frac{<\bar{q}q>_m}{<\bar{q}q>} = 1 - \frac{\sigma_N}{m_\pi^2 f_\pi^2}\left[\frac{m_\sigma^2}{g_\sigma^2}(M_N - M_N^*) + (1+\alpha)\frac{m_\sigma^2}{g_\sigma^2 M_N}(M_N - M_N^*)^2 - \frac{g_\omega^2}{m_\omega^2}\rho^2\right]$$

- Delfino, Coelho, Malheiro

$<qq>_m \to 0$ for $\alpha=1$ (ZM models)

Deep inelastic scattering

$$d\sigma = l_{\mu\nu} W^{\mu\nu}$$

$$W_{\mu\nu} = \sum_x \delta(p + q - r) \langle p | J_{\mu\nu}(\mathbf{0}) | x \rangle \langle x | J_{\mu\nu}(\mathbf{0}) | p \rangle$$

$$W_{\mu\nu} \approx \int d^4\xi e^{iq\xi} \langle p | J_{\mu\nu}(\xi) J_{\mu\nu}(\mathbf{0}) | p \rangle$$

$$W_{\mu\nu} = -(g_{\mu\nu} - q^\mu q^\nu / q^2) W_1(q^2, \nu) + \mathbf{1} / M^2$$

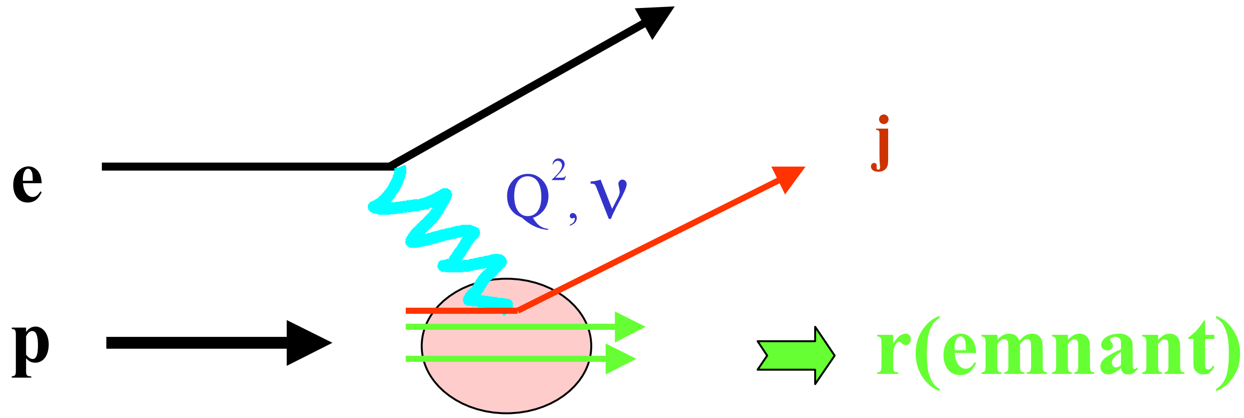
$$(p_\mu - (M\nu / q^2) q_\mu)(p_\nu - (M\nu / q^2) q_\nu) W_2(q^2, \nu)$$

$$(\nu / M) \lim_{\nu \to \infty} W_2(q^2, \nu) = F_2(x_T) \leftarrow Bjorken \quad Scaling$$

$$q = (\nu, \mathbf{0}, \mathbf{0}, -\sqrt{\nu^2 + Q^2}), \qquad Q^2 = -q^2$$

$$q = (\nu, \mathbf{0}, \mathbf{0}, -\nu - Mx) \qquad x_T = Q^2 / \mathbf{2} M\nu \rightarrow fixed$$

D I S



Hit quark has momentum $\quad j_+ = x \; p_+$

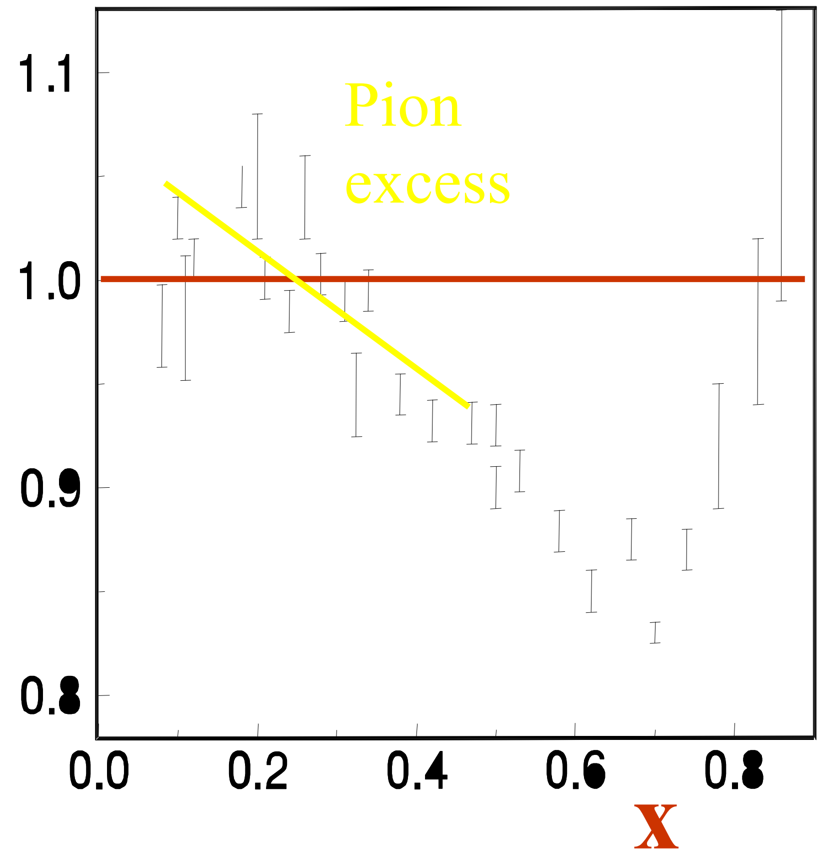
Experimentaly $x = Q^2/2M\nu$
and is iterpreted as fraction of longitudinal nucleon momentum carried by parton(quark) for $\nu^2 > Q^2 \rightarrow \infty$

On light cone Bjorken x is defined as $\quad x = j_+/p_+$
where $p_+ = p_0 + p_z$

EMC effect

Historically ratio

$$\bar{R}(x) = F_2^A(x)/ F_2^N(x)$$



Three approaches to its description:

Three approaches to EMC effect

-

♠ **in term of nucleon degrees of freedom through the nuclear spectral function. (nonrelativistic off shell effects)**

G.A.Miller&J. Smith, O. Benhar, I. Sick, Pandaripande,E Oset

♣ in terms of quark meson coupling model

modification of quark propagation by direct coupling of quarks to nuclear envirovment

A.Thomas+Adelaide/Japan group, Mineo, Bentz, Ishii, Thomas, Yazaki (2004)

♥ **by the direct change of the partonic primodial distribution.**

S.Kinm, R.Close

Sea quarks from pion cloud.

G.Wilk+J.R.,

Today

- We will show that in deep inelastic scattering the magnitude of the nuclear Fermi motion is sensitive to residual interaction between partons influencing both the Nucleon Structure Function

$$\mathbf{F_2^N(x)}$$

- and nucleon mass in th **NM**
- $\mathbf{M_B\ (x)}$

- Relativistic Mean Field problems
- Primodial parton distributions
- Bjorken x scaling in nuclear medium

Change of nucleon primodial distribution inside medium

- *Gaussian distribution of quark momenta* j
- ***Monte Carlo simulations***

$$0 < (j+q) < W$$
$$0 < r < W$$

W - invariant mass

- pion cloud (mass) renormalization

momentum sum rule

- Proton
- Width - .18GeV
- Pion width - 52MeV
- N =7.7 %

- IN MEDIUM

- Proton
- Width - .165GeV
- Pion width =52MeV
- N =7.7 %

Primodial Distributios and Monte –Carlo Simulations

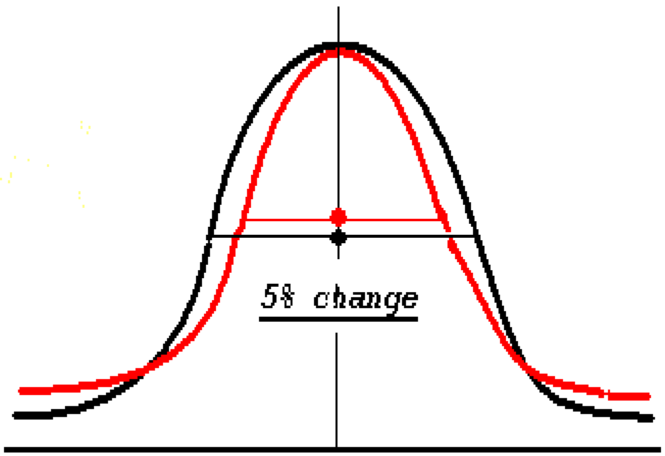
- <u>Calculations for the realistic nuclear distributions</u>

The Change of the primodial disribution in medium

$$\sigma_N = 0.172 \ GeV$$
$$\sigma_\pi = 0.050 \ GeV$$
$$N_{ex} = 12 \ \%$$

$$N(p) = N_{mf}(p) + N_{tail}(p)$$
$$\omega \approx A^{1/3}$$

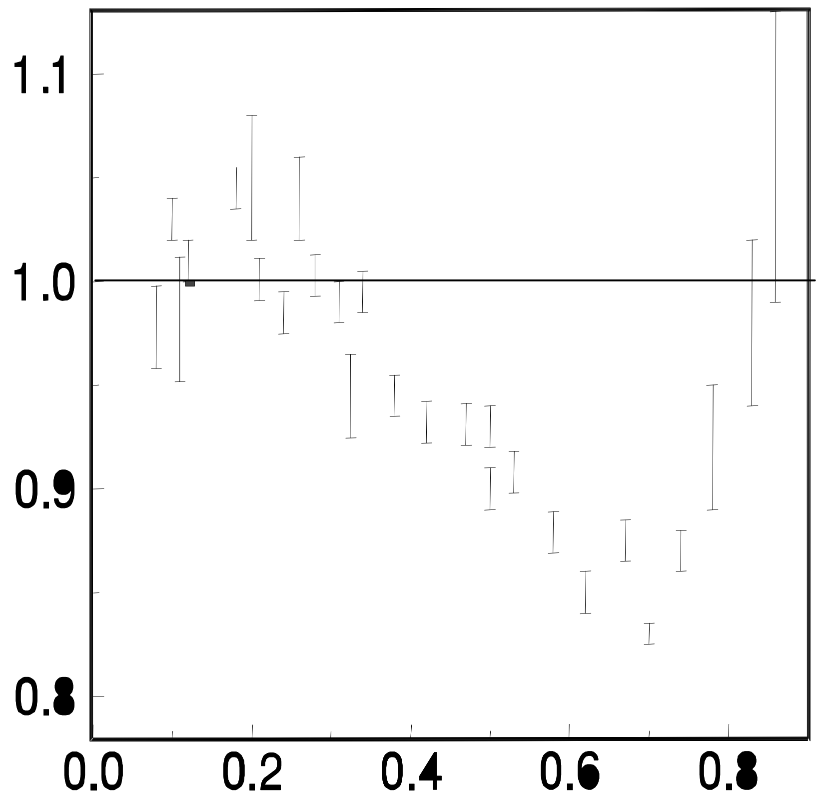
$$N_{tail}(p) = N_C e^{-\beta p} \quad for \quad p > p_C$$



Zabolitsky Ei
Phys .Lett .76 B

$$N_C = 0.021 \ Afm^3$$
$$\beta = 1.5 \ fm$$
$$p_C = 2 \ fm^{-1}$$

Results



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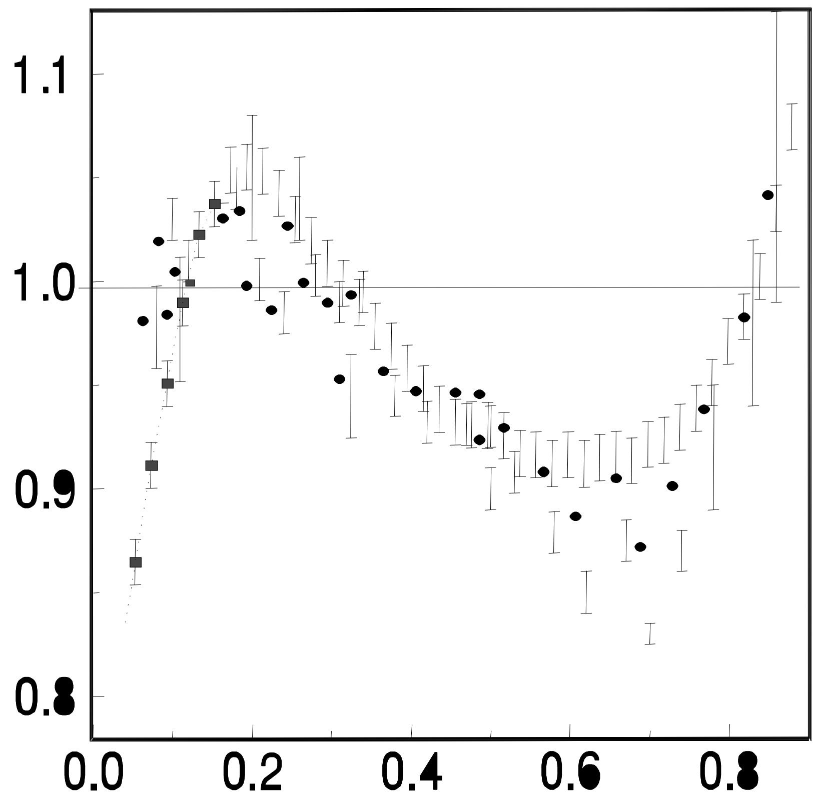
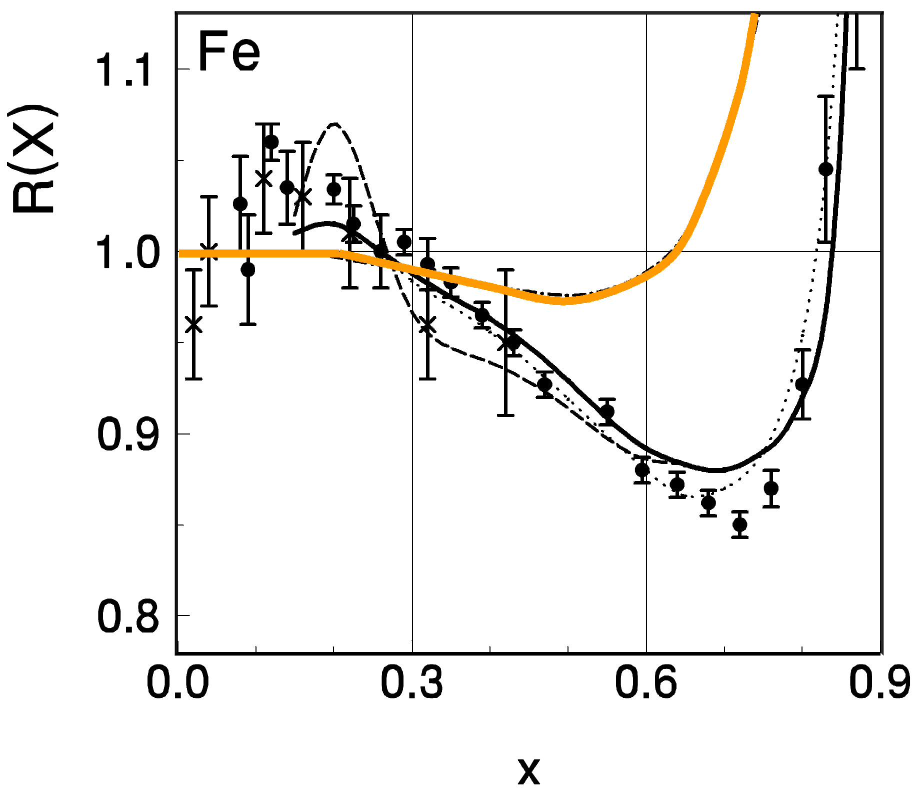


with G. Wilk Phys.Lett. **B473**, (2000), 167

Nuclear Deep Inelastic limit

$$\frac{1}{A}\sum_{i=1}^{nA} j_{Ai}^{+} = \frac{M_A}{A} \equiv M_N + \varepsilon = \sqrt{M_B + \bar{p}^2}$$

$$M_B \cong M_N + \varepsilon - \mathrm{e}_{\mathrm{Fermi}}$$



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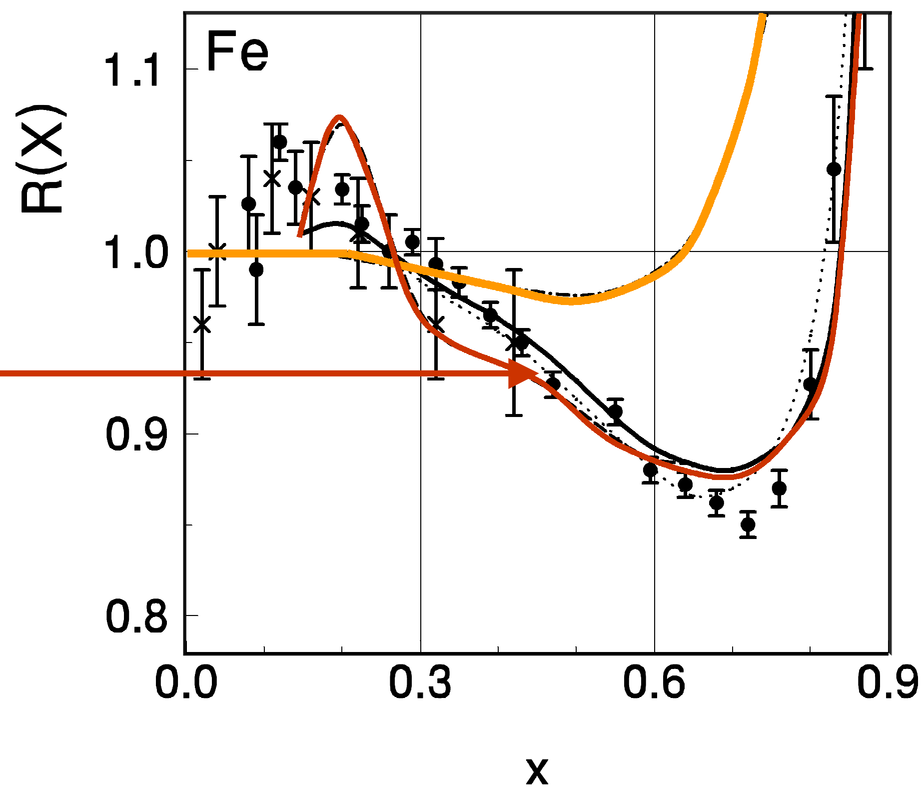

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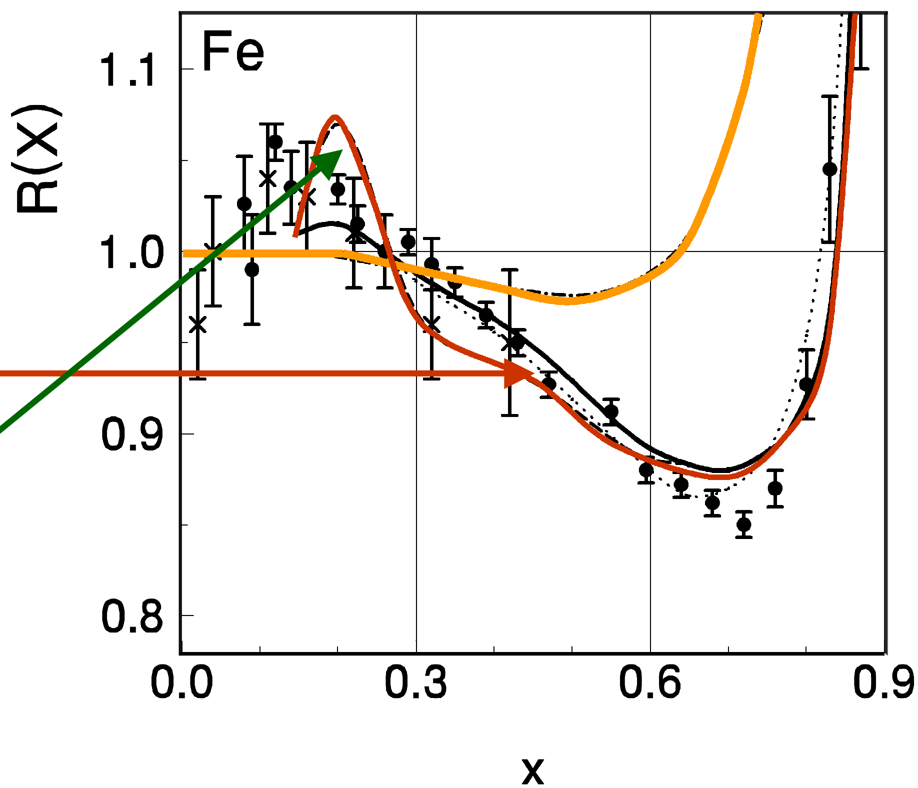
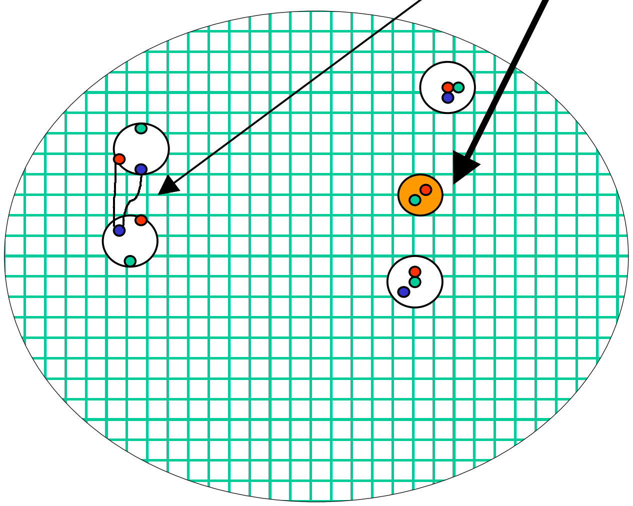
But too much pions



RMF failure &
Where the nuclear pions are



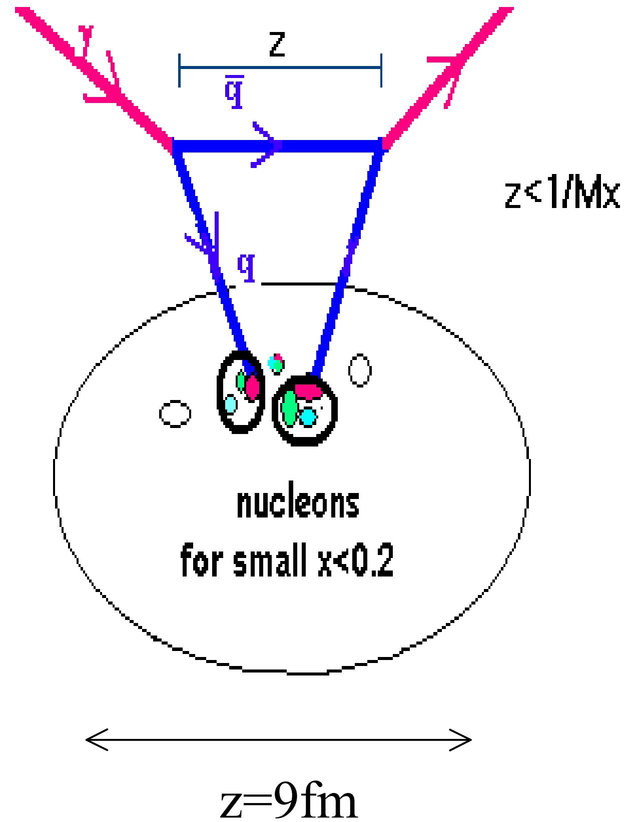
- M Birse PLB 299(1985), JR IJMP(2000), G Miller J Smith PR (2001)
- GE Brown, M Buballa, Li, Wambach , Bertsch, Frankfurt, Strikman

Two resolutions scales in deep inelastic scattering

1. $1/Q^2$ $\rightarrow$ connected with virtuality of γ probe .
   (A-P evolution equation - **well known)**

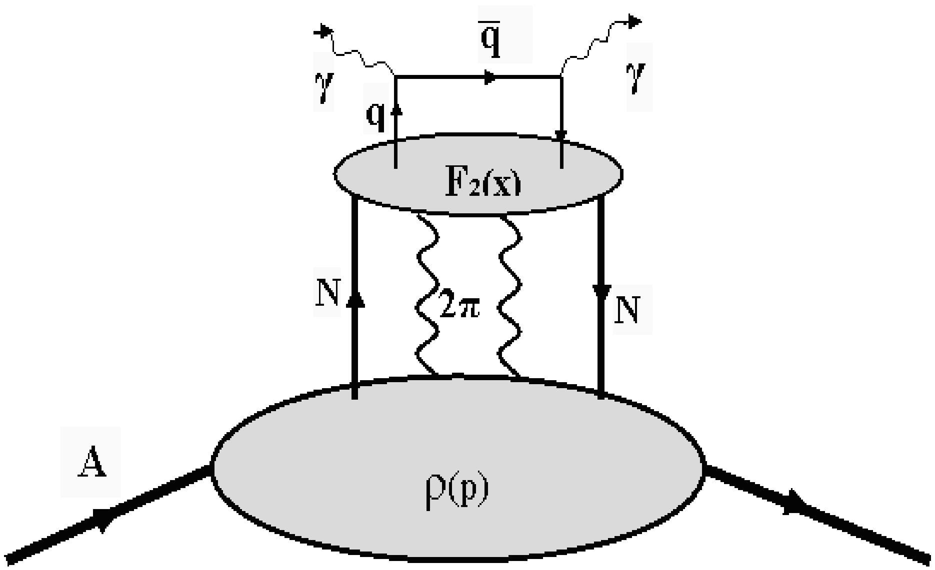
2. $1/Mx = z \rightarrow$distance how far can propagate the quark in the medium.
   q =x M
   (Final state quark interaction - **not known**)

z distance where is shadowing for that pions which carry the nucleon-nucleon interaction

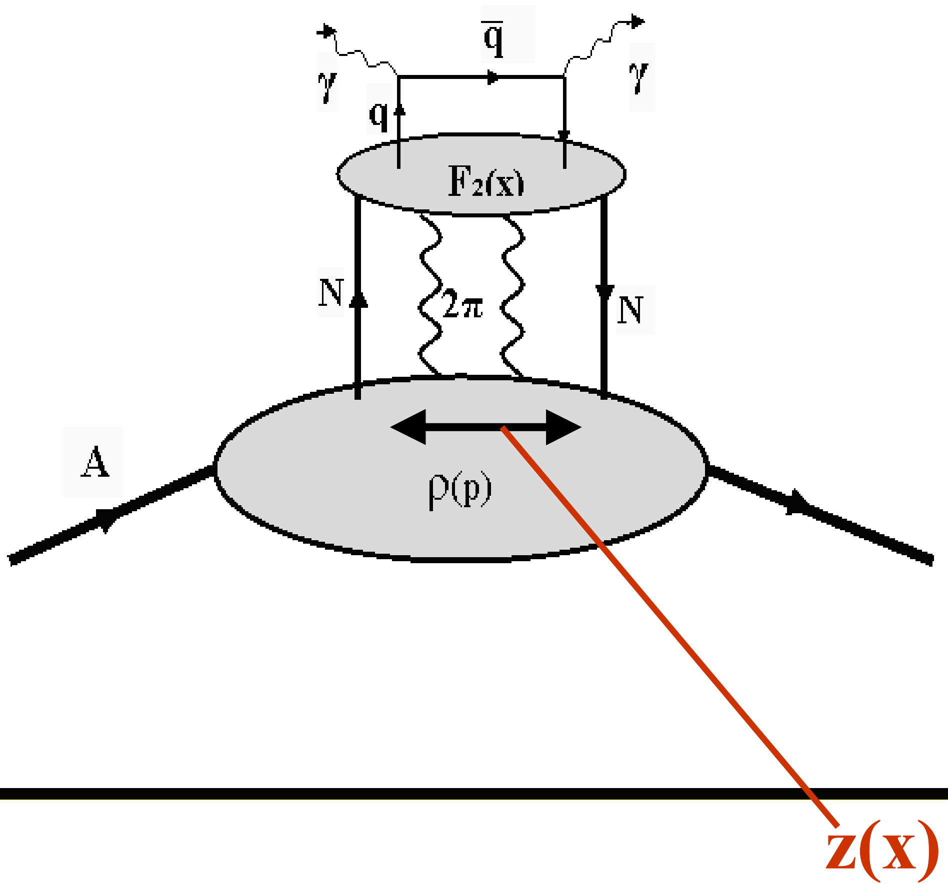


For x=0.05 z=4fm

Nuclear final state interaction



Nuclear final state interaction



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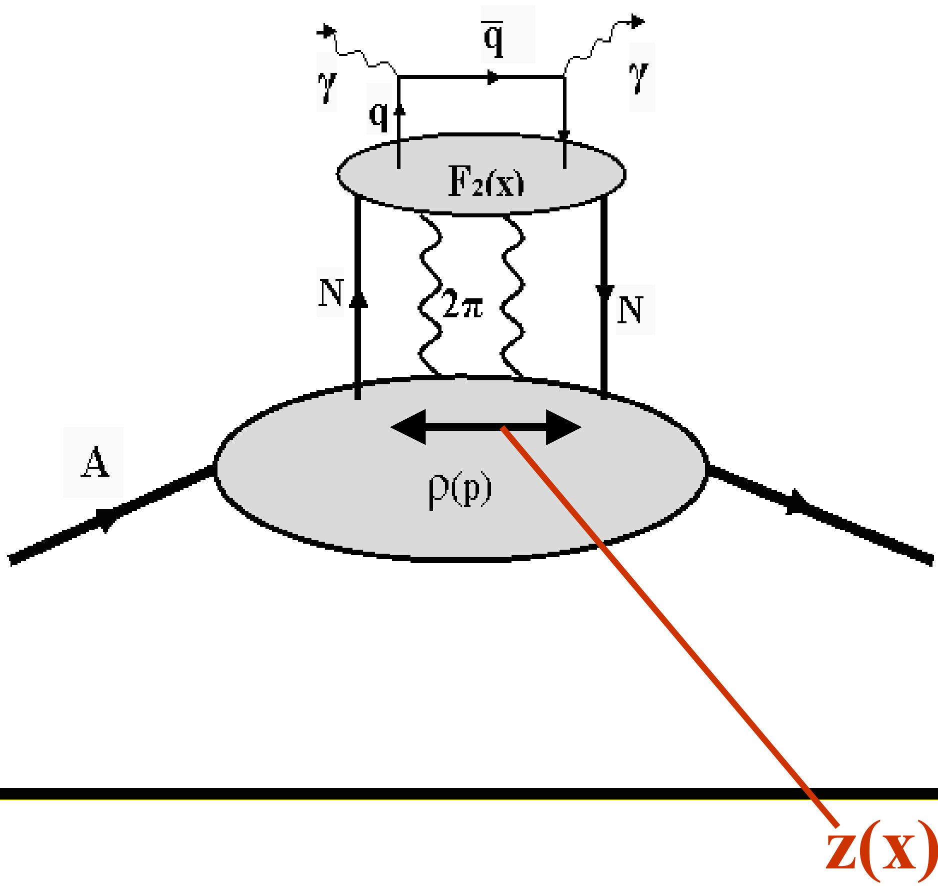


r_N - av. NN distance

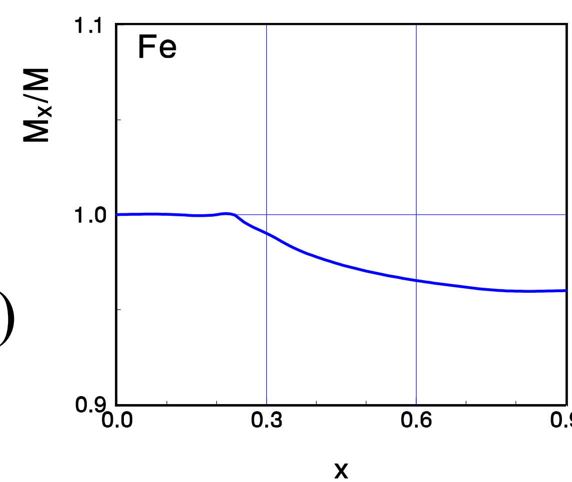
r_C - nucleon radius

if $z(x) > r_N$

$M(x) = M_N$

if $z(x) < r_C$

$M(x) = M_B$

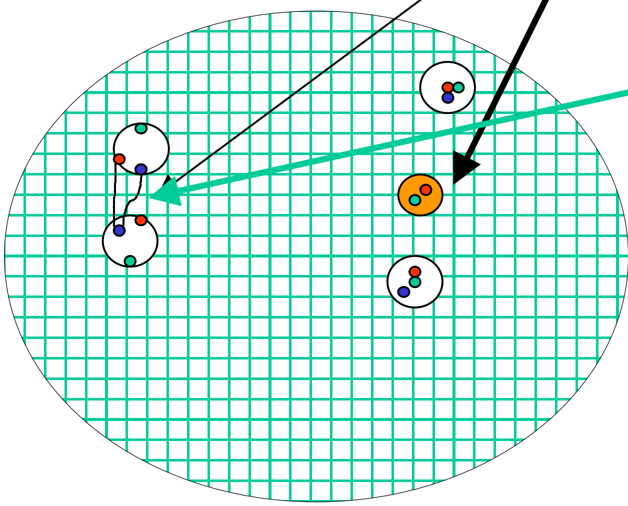


Effective nucleon Mass $M(x)=M(\,z(x)\,,\,r_C\,,r_N\,)$

J.R. Nucl.Phys.A in print

M(x) & in RMF solution the nuclear pions almost disappear

Because of Momentum Sum Rule in DIS



Nuclear sea is enhanced in nuclear medium - pions have bigger mass according to chiral restoration scenario

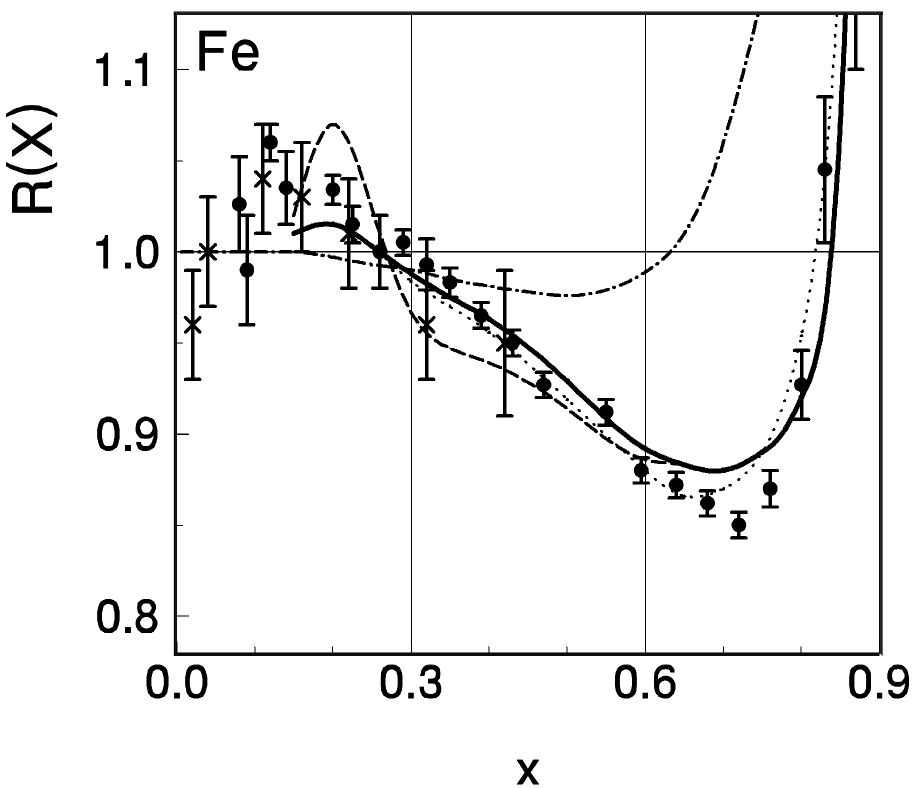
. ***BUT also change sea quark***

. ***contribution to nucleon SF***

rather then additional (nuclear) pions appears

The pions play role rather on large distances?

Results



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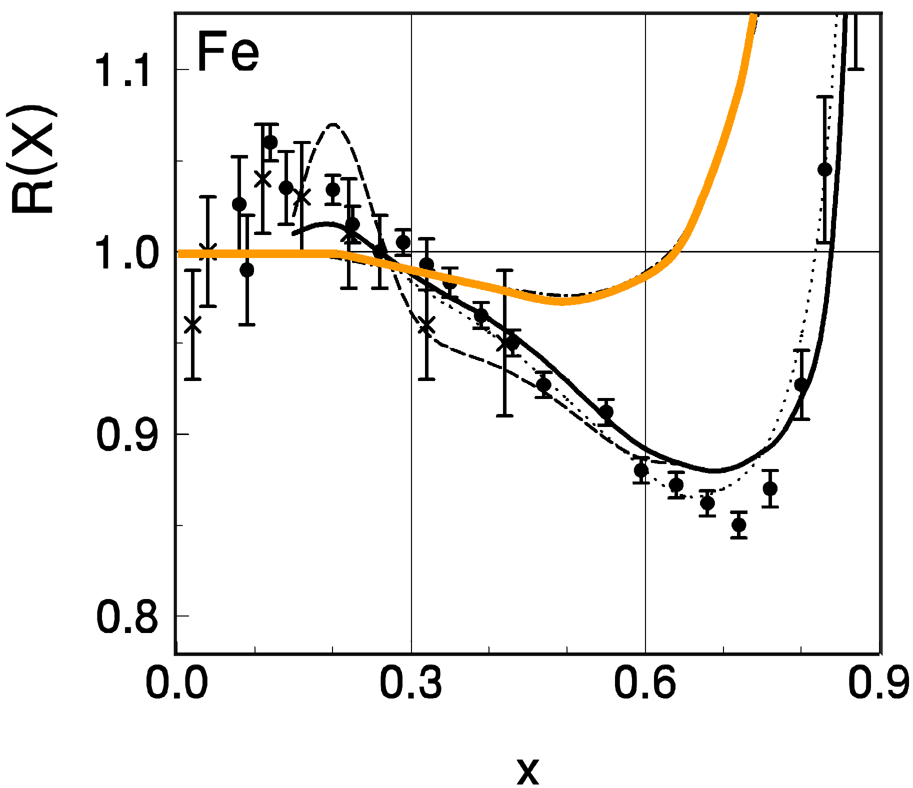
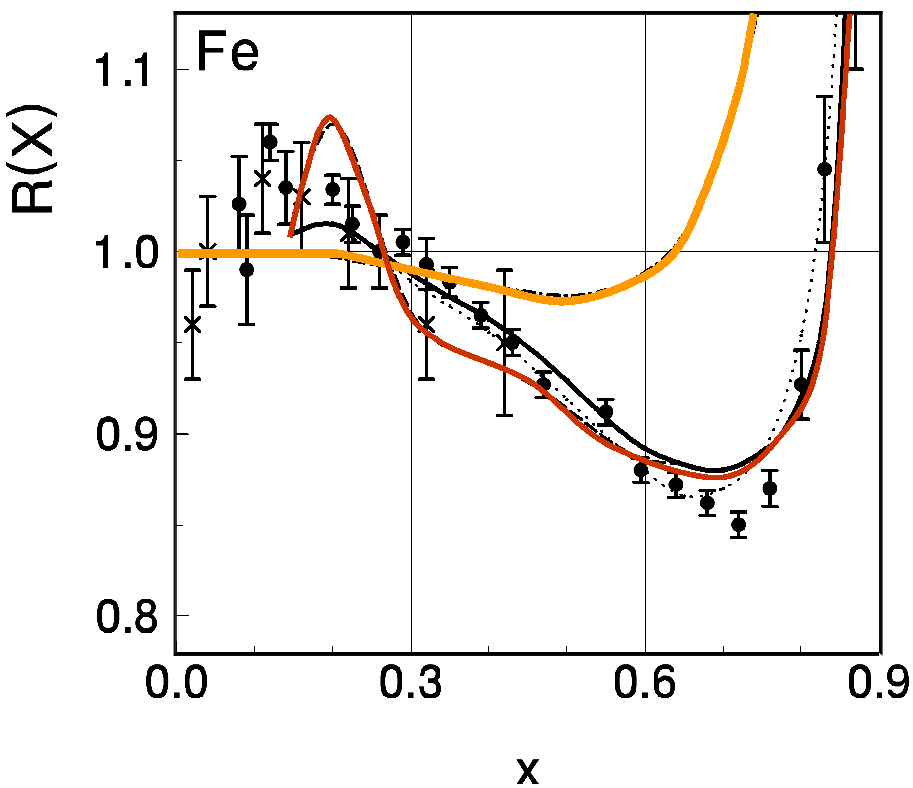


Fermi Smearing

Results

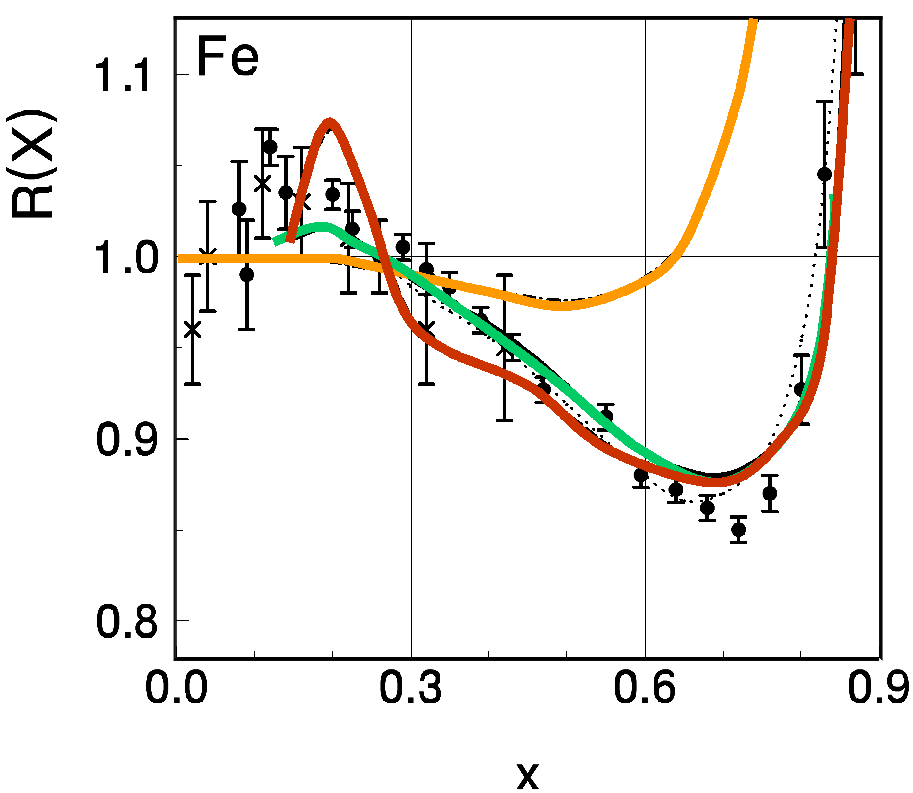


Fermi Smearing

Constant effective nucleon mass

Results

“no” free paramerers



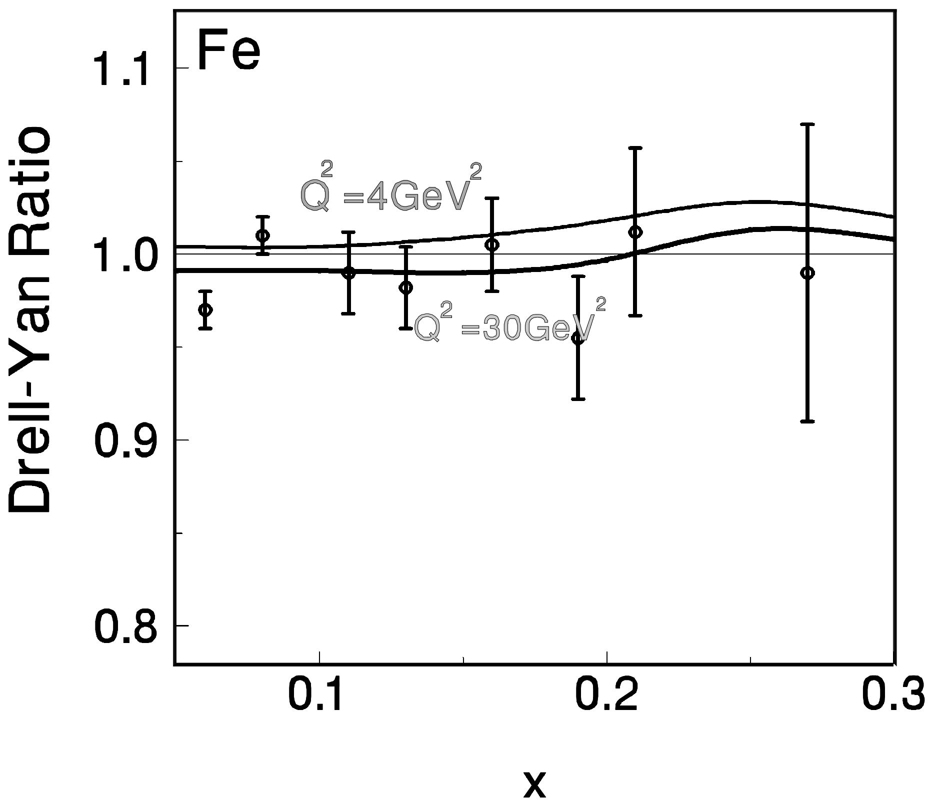
– Fermi Smearing

– Constant effective nucleon mass

– x dependent effective nucleon mass

with G. Wilk Phys.Rev. **C71** (2005)

Drell Yan Calculations



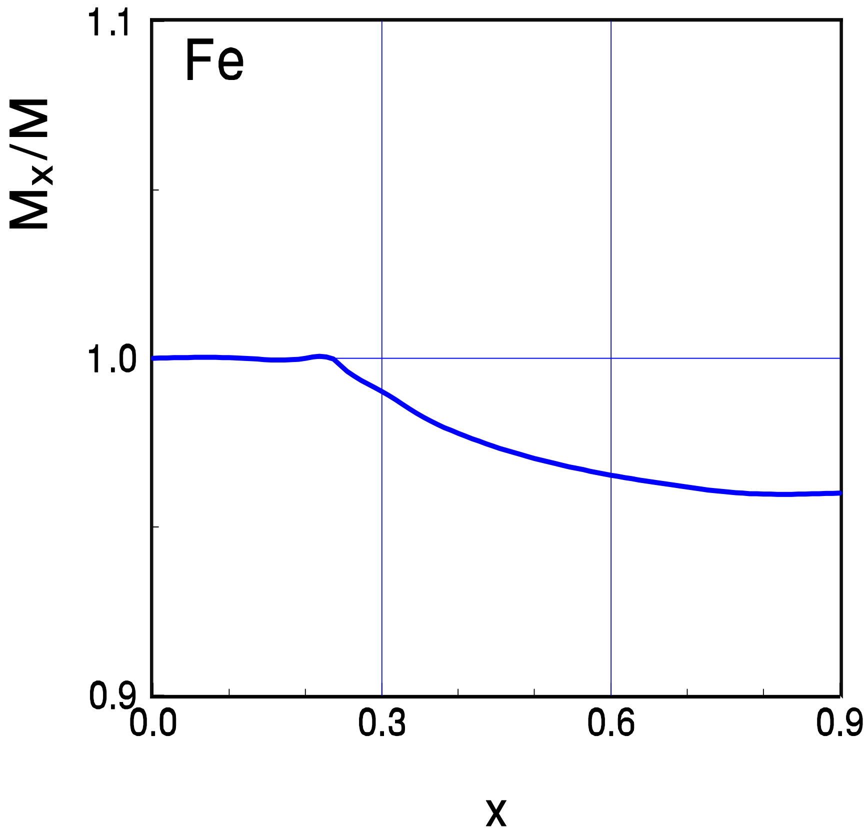
Conclusions

- Good fit to data for Bjorken x>0.1 by modfying the nucleon mass in the medium (~24 MeV depletion) correct the EOS for NM. Although such subtle changes of nucleons mass is difficult to measure inside nuclear medium due to final state interaction this reduction of nucleon mass is compatible with recent observation of similar reduction in Delta invariant mass in the decay spectrum to (N+Pion)
  T.Matulewicz Eur. Phys. J A9 (2000)
- MORE momentum is carried (~ 1% only) by sea quarks (nuclear pions) due to x dependent effective nucleon mass supported by Drell-Yan nuclear experiments.
- Increase of the „additional nuclear pion mass" 5% means that nuclear density is about 2 times smaller than critical .
- x – dependent correction to the $<k_T^2>$ distribution

x dependent nucleon effective mass

- it is possible to show that in DIS $\langle k_T^2 \rangle \sim M^2$

Bartelski Acta Phys.Pol.B9 (1978)



$$\sqrt{\langle k_T^2 \rangle_{Medium} / \langle k_T^2 \rangle}$$

In the x>0.6 limit

(no NN interaction)

$\langle k_T^2 \rangle_{Nuclear} = \langle k_T^2 \rangle_{Nukleon}$

X-N Wang Phys. Rev.C (2000)

Dependence from initial k_T^{2} in p-A collision